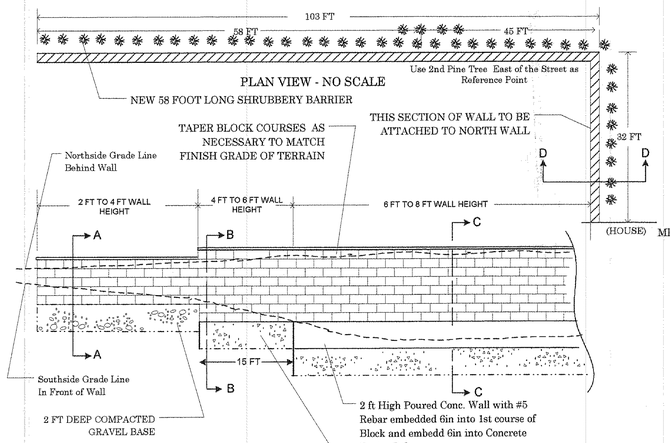
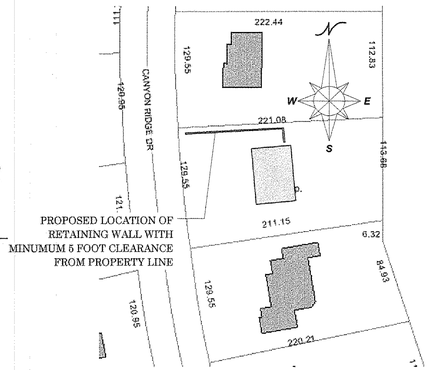
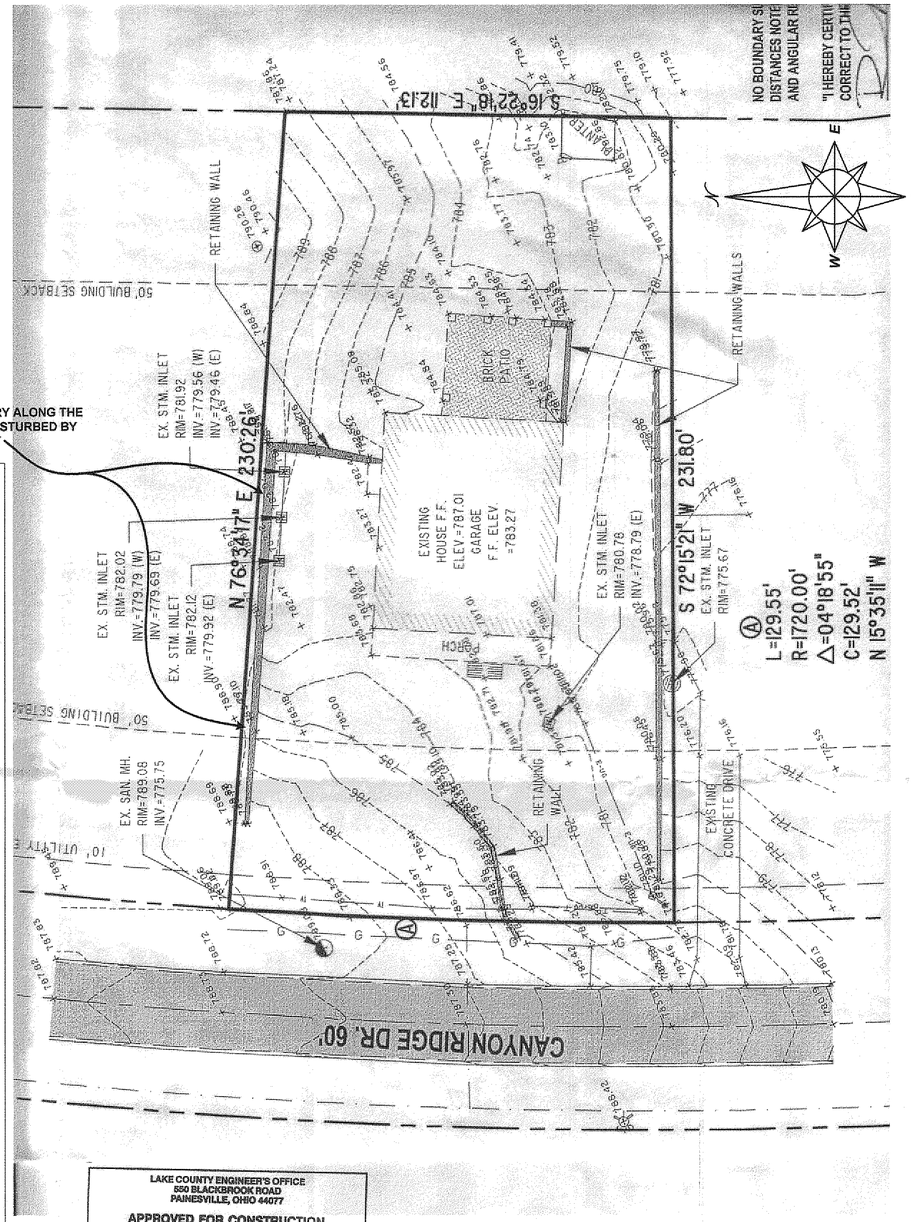
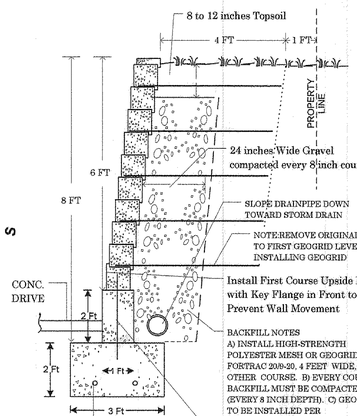


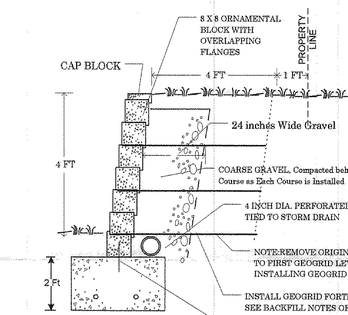


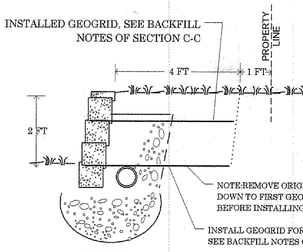
Plot Plan View- Retaining Wall Parcel# 03-002-C-00-010-0
NO SCALE



IMPORTANT NOTE: GEOGRID BOUNDARY ALONG THE LENGTH OF THE WALL IS NOT TO BE DISTURBED BY ANY FUTURE CONSTRUCTION ACTIVITY







SECTION A-A

PROFILES - RETAINING WALL
SCALE : 1/2 INCH = 1 FOOT

Design calculation for retaining wall

Coherent or Geogrid Gravity Walls With Sloped Backfill
Recommended Safety factors Sliding > 1.5 Overturning > 2.0 Internal Compound Stability > 1.3 Global Stability > 1.3

One effect of a sloped backfill on a coherent or Geogrid gravity wall is to increase the weight of the wall and consequently, the resistance to sliding. The increased weight is due to the backfill soil that is located above the wall facing and over the reinforced soil mass. In Figure 1, the area designated Wi contains the soil that contributes the extra weight. The total weight of the wall can be calculated by adding the weight of the rectangular section, Wr to the weight of the triangular section, Wi:
Wr = (130 lb/ft3) (8 ft) (0.97 ft) + (125 lb/ft3) (8ft) (4.0 ft - 0.97 ft) = 4,038.8 lb/ft
Wi = (0.5) (4. 0 ft) [(4.0 ft) tan (18°)] (125 lb/ft3) = 324.9 lb/ft
Ww = (Wr) + (Wi) = (4,039 lb/ft) + (325 lb/ft) = 4,364 lb/ft
External Stability
The external stability of the wall can be calculated as follows. First, the height of the retaining wall is taken to be the height at the back of the reinforced soil mass, the active force on the retained soil mass is greater because of the sloping backfill. The increase in the active force is automatically accounted for by using Coulomb's equation to calculate the active force. This calculation shows the safety factors for sliding and overturning of the wall in Figure 1.
Given:
Phi(i) = 30degrees i = 18degrees H = 8 ft
Phi(w) = 20degrees Beta = 78degrees Gamma r = 120 lb/ft3
Phi r = 27degrees K(ar) = 0.3440 Gamma i = 125 lb/ft3
Phi wr = 18degrees K(ai) = 0.2847
The first step is to calculate the effective height, He at the rear of the coherent gravity wall:
He = (H) + (Lg) tan (i) = (8 ft) + (4 ft) tan (18) = 9.3 ft
Next, the active force on the coherent gravity wall is calculated:
Fa = (0.5) (Gamma r) (Kar) (He) 2 = (0.5) (120 lb/ft3) (0.344) (9.3 ft) 2 = 1,785 lb/ft
The horizontal component of the active force is:
Fh = (Fa) cos Phi (wr) = (1,785 lb/ft) cos (18°) = 1,697 lb/ft

The vertical component of the active force is:
Fv = (Fa) sin Phi (wr) = (1,785 lb/ft) sin (18°) = 551 lb/ft
The force resisting sliding is:
Fr = (Ww + Fv) (Cf) = (4,364 lb/ft + 551 lb/ft) tan (30) = 4,682 lb/ft
The safety factor against sliding is:
SFS = Fr / Fh = (4,682 lb/ft) / (1,697 lb/ft) = 2.75 >1.5 therefore Wall is OK

The moment resisting overturning is:
where:
X1 = distance to the center line AB block
X2 = distance to the center line of the reinforced mass
X3 = distance to the centroid of the backeslope
X4 = distance to the back of the reinforced mass
Mr = (Wf) [(X1) + (0.5) (H) tan (90° -Beta)] + (Wr) [(X2) + (0.5) (H) tan (90° -Beta)]
+ (Wi) [(X3) + (H) tan (90° - Beta)] + (Fv) [(X4) + (0.333) (He) tan (90° - Beta)]
= (760 lb/ft) [(0.49 ft) + (0.5) (8. ft) tan (90° - 78°)] + (4,038 lb/ft) [(3.47 ft) + (0.5) (8. ft) tan (90° - 78°)]
+ (324 lb/ft) [(4. ft) + (8.5 ft) tan (90° - 78°)] + (551 lb/ft) [(6.13 ft) + (0.333) (8.5 ft) tan (90° - 78°)]
= 1018 + 17445 + 1881 + 3709 = 24,053 ft-lb/ft
The moment causing overturning is:
Mo = (Fh) (0.333) (He) = (1,697 lb/ft) (0.333) (9.3 ft) = 5,255 ft-lb/ft
The safety factor against overturning is:
SFO = Mr / Mo = (24,053 ft-lb/ft) / (5,255 ft-lb/ft) = 4.58 >2.0 therefore Wall is OK against Overturning

Internal Stability
The effect of sloping backfill on the bottom layer of geogrid in the wall is shown in Figure 3. The load on a layer of geogrid is given by:
Fg = (Pavg) (dh)
If the wall in Figure 3 had a flat backfill, the load on the bottom layer of geogrid would be:
F1 = (Pavg) (dh)= (0.5) (P1 + P2) (d1 - d2) = (0.5) [(gamma i) (Kai) (d1) cos (Phi wi) + (gamma i) (Kai) (d2) cos (Phi wi)] (d1 - d2)
= (0.5) [(125 lb/ft3) (0.2197) (8 ft) cos (20°) + (125 lb/ft3) (0.2197) (6.6 ft) cos (20°)] (8 ft – 6.6 ft) = 341 lb/ft

Using the Geogrid Fortrac 20/9-20 Product the maximum tested value Fmax = 908 lb/ft. For the wall in Figure 3 with a backfill slope of 26°, Kai = 0.3662 and the load on the bottom layer of geogrid is:
F1 = (Pavg) (dh)= (0.5) [(gamma i) (Kai) (d3) cos (Phi wi) + (gamma i) (Kai) (d4) cos (Phi wi)] (d3 - d4)
= (0.5) [(125 lb/ft3) (0.3662) (8.5 ft) cos (20degree) + (125 lb/ft3) (0.3662) (7.21ft) cos (20degree)] (8.5 ft - 7.21 ft)
= 505 lb/ft FS = 908 / 505 = 1.79 > 1.3 therefore Geogrid Fortrac 20/9-20 is acceptable to use

the Factor of safety for the Internal stability is 1.3
This is a very conservative design approach since the slope of the backfill is closer to 5 or 10 degrees versus an estimated 26degrees for design purposes. Increasing the slope of the backfill from 0° to 26° increased the load on the bottom layer of geogrid by nearly 100%. If the calculated load at any given layer exceeded the allowable design load of the grid, the strength of the grid or additional layers of grid would need to be considered.

Retaining Wall Construction Notes -
1) Existing Soil Conditions at exact Retaining Wall Location - The soil is densely compacted hard clay with some small amounts of gravel evenly dispersed.

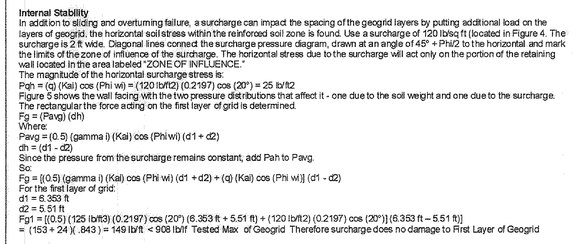
2) Construction Inspection of the wall is required by the registered Engineer responsible for the design. Written documentation of construction activities shall be submitted to the building department for filing purposes.

3) Installation of the Geogrid fabric shall proceed according to the manufacturer's instructions. Emphasis shall be placed on proper attachment of the Geogrid to the blocks and proper preparation, placement and compaction of the gravel backfill.

4) As each course of block is removed to expose the cut clay bank, heavy waterproof tarps shall be attached to the top of the bank and placed on top of any exposed clay bank face to prevent any water from contacting the exposed clay. This is to prevent any water intrusion into the clay bank which would cause the surface and the face of the exposed soil to become unstable. The clay bank shall be re-cut as necessary to allow for a 4 foot wide course of Geogrid to be placed at each alternating block course. As the Geogrid is installed, it is very important that there is proper compaction of the backfill and Geogrid, according to the geogrid manufacturer.

5) After the blockwall is removed, except for the bottom course, the block shall be re-installed to their original placement with the Geogrid attached to each alternating course of block

Various Surcharge Analyses for the Retaining Wall



The coherent gravity wall is analyzed in Diagram 3, with a three-foot-wide dead load surcharge of 120 lb/ft2.
Analyze the external stability of the wall with the surcharge in the three locations shown in Diagram3.
Location A:
The surcharge can be resolved into an equivalent vertical force, Q, of 360 lb/ft that is located 2.33 ft from the front face of the wall and acts at the center of the uniform surcharge. This force can be added to the forces resisting sliding when calculating Fr:
Fr = (Ww + Fv + Q) (Cf) = [(4,364 lb/ft) + (551 lb/ft) + (360 lb/ft)] tan (30Degrees) = 5,123 lb/ft
Figure 3. Locations of Surcharge on Coherent Gravity Walls
The new safety factor against sliding is:
SFS = Fr / Fh = (5,123 lb/ft) / (1,697 lb/ft) = 3.02 >1.5 therefore Wall is OK with Surcharge at Location A
Q is added to the moments of the forces resisting overturning.
X1 = distance to the center line of the reinf. mass , X2 = distance to the back of the reinf. Mass, X3 = distance to the centerline surcharge
SUMMr = (Ww) [(X1) + (0.5) (H) tan (90° - Beta)] + (Fv) [(X2) + (0.333) (H) tan (90° - beta)] + (Q) [(X3) + (H) tan (90° - Beta)]
= (4,364 lb/ft) [(2.66 ft)+(0.5)(8 ft) tan(90°-78°)]+(551 lb/ft) [(4.66 ft)+(0. 333)(8 ft) tan(90° -78°)]+(360 lb/ft) [(2.33 ft)+(8 ft) tan(90° - 78°)]
= 15,319 +2,880 + 1,451 = 19,650 ft-lb/ft

SUMMo = (Fh) (0.333) (H) = (1,697 lb/ft) (0.333) (8 ft) = 4,521 ft-lb/ft
The new safety factor with surcharge against overturning is:
SFO = SUMMr / SUMMo = (19,650 ft-lb/ft) / (4,521 ft-lb/ft) = 4.34> 2.0 Therefore Wall is OK with Surcharge at Location A

Location B:
A surcharge in this location has the same effect on the external stability of a coherent gravity wall as on a simple gravity wall. In this case, the surcharge results in a horizontal force with its point of application located at H/2 on the back of the reinforced soil mass. The magnitude of the force is:
Fq = (q) (Ka) (H) = (120 lb/ft2) (0.2561) (8 ft) = 246 lb/ft
The horizontal and vertical components of the force on the reinforced soil mass due to the surcharge are:
Fqh = (Fq) cos (Phi wr) = (246 lb/ft) cos (18°) = 234 lb/ft
Fqv = (Fq) sin (Phi wr) = (246 lb/ft) sin (18°) = 76 lb/ft

For Location B, the safety factors against sliding and overturning are:
SFS = [Fr + (Fqv) (Cf)] / [Fh + Fqh] = [5,123 lb/ft + 76 lb/ft tan 27°] / [1,697 lb/ft +234 lb/ft] = 2.67 > 1.5 OK, Surcharge Location B

SFO = (SUMMr + (Fqv) [(X2) + (0.5) (H) tan (90° - Beta)]) / (SUMMo + (Fqh) (0.5) (H))
SFO = 19,650 ft-lb/ft + 76 lb/ft (4.13 ft + (0.5) (8 ft) tan (90° - 78°)] / [4,521 ft-lb/ft + (234 lb/ft) (0.5) (8 ft)]
SFO = 20,028 / 5,457 = 3.67 > 2.0 Therefore Wall is OK against Overturning with surcharge at Location B

Location C:
With the surcharge at Location C, half of the surcharge is over the reinforced soil zone and half is not. Therefore, the effects on the coherent gravity wall are a combination of the effects of a surcharge at Location A and a surcharge at Location B. The part of the surcharge over the geogrid will contribute to the stability of the wall with respect to sliding and overturning. The horizontal and vertical components of the force on the reinforced soil mass due to the surcharge are:
Fq = (q) (H) (Ka) = (120 lb/ft2) (8 ft) (0.2561) = 246 lb/ft
Fqh = (Fq) cos (Phi wr) = (246 lb/ft) cos (18degrees) = 234 lb/ft
Fqv = (Fq) sin (Phi wr) = (246 lb/ft) sin (18degrees) = 76 lb/ft
The force resisting sliding is:
Fr = [Ww + Fv + 0.5 (Q) + Fqv] (Cf) = [4,364 lb/ft + 551 lb/ft + 180 lb/ft + 76 lb/ft] tan 30degrees = 2,985 lb/ft
The force causing sliding is:
Fs = Fh + Fqh = 1,697 lb/ft + 234 lb/ft = 1,931 lb/ft
The safety factor against sliding is:
SFS = 2,985 / 1,931 = 1.54 > 1.5 Therefore Wall is OK against sliding at Location C

The sum of the moments resisting overturning is:
SUMMr = (Ww)[(X1)+(.5H) tan(90°-Beta)]+(Fv)[(X2)+(0.333H)tan(90°-Beta)]+(Fqv)[(X2)+(.5H)tan(90°-Beta)]+ (.5Q)[(X3)+(Htan(90°-Beta)]
= (4,364 lb/ft) [(2.33 ft)+(4ft)tan (12°)]+(551 lb/ft) [(4.66 ft)+(2.67 ft)tan (12°)]+(76 lb/ft) [(4.66ft)+(4ft)tan (12°)]+(180lb/ft) [(3.5ft)+(8ft) tan12°
= 13,878 + 2,880 + 419 + 936 = 18,113 ft-lb/ft
The sum of the moments causing overturning is:
SUMMo = (Fh) (0.333) (H) + (Fqh) (0.5) (H) = (1,697 lb/ft) (0.333) (8 ft) + (234 lb/ft) (0.5) (8 ft)
= 4,989 ft-lb/ft
The safety factor against overturning is:
SFO = (18,113 ft-lb/ft) / (4,989 ft-lb/ft) = 3.63> 2.0 Therefore Wall is OK against Overturning at Location C

Internal Stability
In addition to sliding and overturning failure, a surcharge can impact the spacing of the geogrid layers by putting additional load on the layers of geogrid. the horizontal soil stress within the reinforced soil zone is found. Use a surcharge of 120 lb/sq ft (located in Figure 4. The surcharge is 2 ft wide. Diagonal lines connect the surcharge pressure diagram, drawn at an angle of 45° + Phi/2 to the horizontal and mark the limits of the zone of influence of the surcharge. The horizontal stress due to the surcharge will act only on the portion of the retaining wall located in the area labeled "ZONE OF INFLUENCE."
The magnitude of the horizontal surcharge stress is:
Pqh = (q) (Kai) cos (Phi wi) = (120 lb/ft2) (0.2197) cos (20°) = 25 lb/ft2
Figure 5 shows the wall facing with the two pressure distributions that affect it - one due to the soil weight and one due to the surcharge. The rectangular the force acting on the first layer of grid is determined.
Fg = (Pavg) (dh)
Where:
Pavg = (0.5) (gamma i) (Kai) cos (Phi wi) (d1 + d2)
dh = (d1 - d2)
Since the pressure from the surcharge remains constant, add Pah to Pavg.
So:
Fg = [(0.5) (gamma i) (Kai) cos (Phi wi) (d1 + d2) + (q) (Kai) cos (Phi wi)] (d1 - d2)
For the first layer of grid:
d1 = 6.353 ft
d2 = 5.51 ft
Fg1 = [(0.5) (125 lb/ft3) (0.2197) cos (20°) (6.353 ft + 5.51 ft) + (120 lb/ft2) (0.2197) cos (20°)] (6.353 ft – 5.51 ft)]
= (153 + 24)(.843) = 149 lb/ft < 908 lb/f Tested Max of Geogrid Therefore surcharge does no damage to First Layer of Geogrid

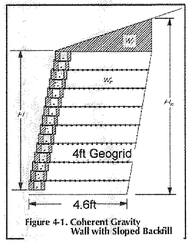


Figure 4-1. Coherent Gravity Wall with Sloped Backfill

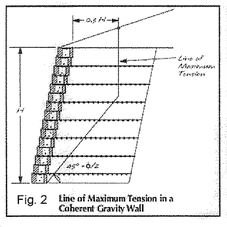


Fig. 2 Line of Maximum Tension in a Coherent Gravity Wall

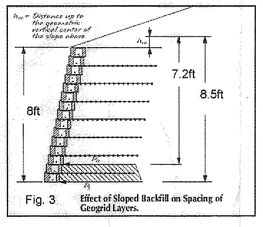


Fig. 3 Effect of Sloped Backfill on Spacing of Geogrid Layers.

LAKE COUNTY ENGINEER'S OFFICE
550 BLACKBROOK ROAD
PAINESVILLE, OHIO 44077
APPROVED FOR CONSTRUCTION
Checking is only for general conformance with the design concept of the project and general compliance with the information given in the contract documents. Any action shown is subject to the requirements of the plans and specifications. The contractor is responsible for dimensions which shall be confirmed and correlated at the job site; fabrication processes and techniques of construction; coordination of his work with that of all other trades; and the satisfactory performance of his work.
2/22/10 By _____, P.E.

Plot Survey Parcel# 03-002-C-00-010-0

Scale: 1 in. = 20 ft.

RETAINING WALL NOTES:

1) RECONSTRUCTION AND REINSTALLATION OF THE WALL WITH INSTALLATION OF THE GEOGRID MUST OCCUR WITHIN ONE WEEK OF INITIAL EXCAVATION TO PREVENT FAILURE OF THE CUT CLAY BANK TO MAINTAIN ITS STABILITY.
2) WALLS GREATER THAN 4 FT HIGH REQUIRE A CONCRETE FOOTER REINFORCED WITH REBAR
3) EXISTING SOIL BEARING STRENGTH = 2,000 PSI
4) THIS WALL SYSTEM IS NOT TO BE DISTURBED WITH ANY FUTURE CONSTRUCTION ACTIVITES
5) VEHICLES ARE PROHIBITED FROM DRIVING WITHIN 10 FEET OF THE TOP EDGE OF THE WALL ON THE NORTH SIDE OR BACKFILLED SIDE OF THE WALL
6) PEDESTRIAN BARRIER PROVIDED BY MEANS OF DENSE SHRUBBERY.
7) CALCULATIONS, AS SHOWN ON THIS PAGE, VERIFY THE GLOBAL STABILITY OF THE GRAVITY-BASED DESIGN.
8) ALL ASPECTS OF WALL CONSTRUCTION TO BE INSPECTED BY THE ENGINEER OF RECORD

PLAN VIEW OF INTERLOCKING RETAINING WALL AND DETAILS
Residence at Parcel# 03-002-C-00-010-0, 5615 Canyon Ridge Drive, Perry, OH 44081

Eric A. Satler
PH. 440-259-2848
02/22/2010

STATE OF OHIO · ERIC A. SATLER · E-49084 · REGISTERED · PROFESSIONAL ENGINEER

Residence at Parcel# 03-002-C-00-010-0
INTERLOCKING WALL RETAINER PROJECT
Jayse Patel, Home Owner
REV 0

SCALE	VARIOUS	FEB 22, 2010	DRAWN BY EAS	SHEET	1 OF 1